Development of Automatic Firing Angle Calculation for Ground to Ground MLRS

Weerawut Charubhun and Pawat Chusilp
Defence Technology Institute
Nonthaburi, Thailand
weerawut.c@dti.or.th, pawat.c@dti.or.th

Abstract—**This paper addresses a method to determine firing angles of an unguided ground to ground Multiple Launched Rocket System (MLRS). Six-degree of freedom trajectory simulation is used in prior to reveal all firing ranges of each firing angle and possible scenarios can be categorized. Some firing range can be achieved by two different firing angles while the others can be achieved by only one firing angle. By having prior knowledge of the firing ranges versus the firing angles, and by employing iterative binary search algorithm and six-degree of freedom trajectory calculation, the method to automatically and iteratively search for a firing angle corresponded to a specified firing range is formed. The method is tested with short range and medium range unguided ground to ground rockets at various firing condition. The results are presented and discussed.**

Keywords—Fire control program, Trajectory simulation, Missile trajectory, Binary search, Firing tables

I. INTRODUCTION

Modern unguided ground to ground Multiple Launched Rocket Systems (MLRS) are mostly equipped with automatic fire control systems that calculate the firing angles – azimuth and quadrant elevation for a given target. To develop a fire control program, one may utilize STANAG 4119 [1] and Five-degree of freedom (5DOF) [2] or Six-degree of freedom (6DOF) trajectory calculation [3,4] to develop tabular data of firing tables. By knowing range and direction from a launcher to a target, launcher altitude, and target altitude as a primary index and by having meteorological data for correction parameters, the gunner can perform table lookup to determine corresponding firing angle solutions [5]. Alternatively, those tabular data can be uploaded to a fire control computer as well as an interpolation or look-up table algorithms to automatically carry out the calculation. Either by hand calculation or a computer, this approach needs to generate a set of tabular firing tables and stored them in a computer prior to the calculation.

Another approach does not involve the generation of the tabular firing tables but takes advantage of a modern computer technology to iteratively calculate the firing range at a given firing angle and condition at very high computing speed until the firing angle solution is converged. This approach also has an advantage of being able to include more non-standard conditions and more sophisticated meteorological model [6] to acquire more accurate firing angle solution. A well-known work of fire control programs, NATO Armaments Ballistic Kernel (NABK) [7] employs such method uses 5DOF model for rocket dynamics. Unfortunately, the insight details of the program are mostly classified. A hybrid method, combining the use of iterative 6DOF calculation and pre-calculated tabular firing data together, is also possible [8].

This paper presents one of many alternative ways to develop a fire control algorithm using a pure iterative calculation approach. The presented method employs a classical binary search and a 6DOF trajectory model to converge the firing solution. Pre-calculated tabular firing data is not required. A short range (10 km) and a medium range (180 km) unguided ground to ground artillery rockets are employed to test the algorithm. The firing range versus quadrant elevation of the rocket is investigated. The result of the investigation forms the structure of the fire control algorithm. The algorithm is verified by comparing the calculated firing angle solutions to a known calculated answer.

II. QUARDRANT ELEVATION VERSUS RANGE ANALYSIS

In aiming a rocket, quadrant elevation (QE) and azimuth (AZ) are the two angles that are fed to the launch platform controller. Quadrant elevation is the angle between the longitudinal axis of launch tube and the perfect ground level. The azimuth is the angle in lateral plane, which is frequently measured from north direction. The fire control system is responsible for calculating these angles from the given launcher and target positions.

Every ground to ground rocket system has operational limitations due to its mechanism or terrain conditions. These parameters concerning the limitation are the minimum (QE_{min}) and the maximum (QE_{max}) quadrant elevation. The minimum quadrant elevation gives the shortest firing range (R_{QEmin}). The maximum firing angle gives the highest altitude a rocket can reach (H_{max}) and the range at maximum search angle (R_{QEmax}) as shown in Fig. 1.

For typical projectiles, including unguided ground to ground rockets, the firing range increases as QE increases until it reaches the maximum firing range (R_{QE_Rmax}). After the maximum range is reached, the firing range decreases as QE increases. Different rocket have different values of QE that

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